Cavity magnetron in Russia

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Abstract— **The first domestic researches of the cavity magnetron in Russia were in the thirties of the XXnd century. In the paper it is told about destinies of the first researchers (including D. Malyarov and N. Alekseev). The Second World War not only has changed the approach to cavity magnetron development and to their practical application, but also has caused a set of transformations to the industries. There were new state decisions, enterprises, names. The further evolution of magnetron development occurred within a restriction of access to the information which has become partially excellent only ~~last~~ in recent years. In the paper a short characteristic of history and development of the magnetron tendencies on the basis of the domestic industry is presented.**

Keywords- cavity magnetron, radar, Malyarov, Alekseev, Bonch-Bruevich

I. INTRODUCTION

The Magnetron causes a lot of interest as it is the first truly large-scale production microwave-device; remember about the radar and microwave ovens. The historical roots of magnetrons, as technical tools that use electromagnetic radiation, arose during the second half and the end of XIX century. This proposed paper on the establishment and development of cavity magnetrons in Russia covers various periods in the history of the Russian State. The history of the cavity magnetron is closely connected with the radars.

II. BACKGROUND

Birth of domestic cavity magnetrons occurred in the thirties of the XX century. In retrospect, considering the state of Radio Engineering in the 1930s, it should be noted that the magnetrons did not appear out of nowhere. According to the principle of action and area of implementation, the magnetrons are related to electronics and radio technology devices. The foundation of electronics and radio technology has been laid down by works of physicists (scientists and engineers) from many countries. As is known, the most significant gains were observed from the end of the XIX century to the beginning of the XX century: the discovery of the electromagnetic field and radio waves, the creation of the first radio communication device and the first electronic amplifier tubes. Physical and technological bases of the magnetrons began to form in 1920, thanks to the work of scientists from different countries also. The first scientific ideas of object~~s~~ detection using radio waves were already known at that time - a prototype of the functioning principle of the radar. But these were only ideas. For their implementation at least two conditions were needed: the emergence of demand for such equipment and the availability of industry, ready to produce the new equipment in adequate quantities. Remember these two conditions - they played a major role in the development of magnetrons in Russia. The first of these was the powerful impetus for the development of theoretical and practical research in the field of microwave technology (including magnetrons). The second condition was realized only in the postwar years. Therefore, looking ahead, it is just worth noting that many successful technological and engineering solutions of Soviet scientists and engineers, which they made in the 1930s, remained “on paper”, due to the weakness of industry.

So back to the mid 1920s. An industrial crisis was gradually "covering" industrialized Western countries. In the Soviet Union the opposite situation was starting at this time. The young Soviet Republic on its way out of the crisis caused by the revolution and civil war entered the path of industrialization. Stalin announced the “Great Change”, the “offensive of socialism along the whole front”, the accelerated transformation of the Soviet Union into a great industrial power. Much attention has been paid to technological developments, scientific research and support of universities in the mid 1920s. But even earlier, in 1918, the development of radio engineering in the country was supported by the Soviet government by creating the Nizhny Novgorod Radio Laboratory (NRL). This happened just one year after the revolution, during hunger, devastation and civil war. Many engineers worked in the NRL, then returned to Leningrad, began research on magnetrons (in particular, Malyarov and Bonch-Bruevich). Bonch-Bruevich constructed the world's first powerful generator tubes with water-cooled copper anodes in this laboratory when he worked in NRL.

Subsequent years have seen intense development in the Soviet Union of different types of electron tubes, starting from tetrode (1924) and pentode (1930) and ending with the combined and multigrid tubes. In 1930, A. Ostryakov proposed air-cooling high-power generator tubes, in 1933 - 1934 A. L. Mintz and N. I. Stanov constructed demountable powerful generator tubes, improved afterwards by A. M. Kugushev and his staff. It is noteworthy to outline the work of the Leningrad factory "Svetlana" in this direction.

The establishment of radiolocation was followed by the research of VHF propagation over the earth's surface. Special merits in this research belong to the Soviet Academician B. A. Vvedenskiy – a future member of the team developed magnetrons in Scientific Research Institute – number 9 (SRI-9). The theoretical aspects of VHF propagation and engineering calculations were done not only by B. A. Vvedenskiy, but by many other Soviet scientists such as A. G. Arenberg, V. A. Fock, L. I. Mandel'shtam, N. D. Papaleksi, A. N. Shchukin. Soviet scientists developed and created various antennas in the 1920-1930s of the XX

century such as M. V. Shuleikin, D. A. Rozhanskii, I. G. Klyatskin, A. A. Pistol'kors, who are known world wide.

V. V. Tatarinov, M. S. Neiman, B. V. Braude, S. I. Naidenko, G. Z. Aizenberg, M. A. Bonch-Bruevich *et al* worked successfully in the field of HF antennas.
The first articles of the Soviet scientists devoted to magnetrons have appeared in 1924.
Thus, in the 1920-1930s the theoretical background of microwave technology and radar had been established. Teams of the developers in Leningrad, Kharkov, Nizhny Novgorod (Gorky) were formed. These teams have formed the scientific basis for future radar projects, including magnetrons.

III. PRE-WAR PERIOD

A. *Scientific background of the first radar projects*

The need for radio- based aircraft detection came after the success of military aviation in the late 1920s and early 1930s (aircraft increased their speed and maximum altitude). It was discovered at that time, that optical and acoustic detectors used, can not cope with their task.

The first project on radio-based aircraft detection was initiated by the military gunners. It was not easy to find contractors immediately. They were wanted since 1932. First, civil and military experts declined to participate in the project, referring to the unreality of radio-based aircraft detection sets. The motivation of refusal was justified. The scientific and technical literature of those years did not contain any information on reflection of electromagnetic waves from aircrafts.

Known observations of reflections of radio waves done by G. Hertz, A. S. Popov, American scientists A. Taylor and L. Young, and Soviet specialists M. A. Bonch-Bruevich and A. G. Arenberg and B. A. Vvedenskiy and others, undertaken by them in 1920-1930, were not able to become a reference for any engineering calculations of radar devices.

In those years these supervisions did not confirm possibility of practical use of the reflected radio-waves for the warning about planes in the air. Radio communication equipment had not been able to secure the necessary tactical and technical characteristics of radio-based aircraft detection sets (there was no corresponding element base), and the industry was not ready for mass production of such sets, even if we could invent the necessary radioelements. Besides the military formulated strict specifications and wanted to quickly get a result.

Soviet scientists believed in the possibility of the radio detection and ranging (radar!) technique and began to work actively with the military after the success of an aircraft radio direction-finding experiment. The Central Radio Laboratory (CRL) made this experiment in St.-Petersburg on 3rd January, 1934 under the contract with military gunners, concluded in October 1933.

At the initial stage of radar development two National Commissariats of Defense of the Worker's-Peasant's Red Army ((NCB WPRA) represented the interests of the military: the Main Artillery Administration (MAA) and the Anti-aircraft Defence Administration (ADA). The Communication Department joined to them later.

Technical requirements of these two Customers was different. It was enough to define two coordinates of the aircraft for ADA. It was important to define three coordinates of the aircraft (and it was more exactly!) for MAA. As a result two groups of the radar projects started. Warning radars were developed for the service of a military supervision, notification and communication under ADA orders. Radio Direction Finder (RDF) apparatus (radar stations for an anti-aircraft artillery) were developed under MAA orders .

If we analyze the technical nature of orders, it becomes clear that duplication of work and the artists took place in order to find optimal solution.

The information showing gradual formation of radar scientific base from scientific schools is presented in the Table 1. Radar scientific schools are numbered (from 1 to 6).

The first Radar Scientific School (Table 1) worked only for MAA orders. First, works were carried out in CRL (Leningrad), then (in 1935) were transferred to Central Military-Industrial Radio Laboratory (CMIRL) in Gorky. This scientific school existed during the years 1934-1937. Given the good alternative results (second Radar Scientific School), the further duplication of these works were discontinued.

A second Radar Scientific School worked for MAA and ADA orders. First, works were carried out in Leningrad Physical-Technical Institute (LEPhI)

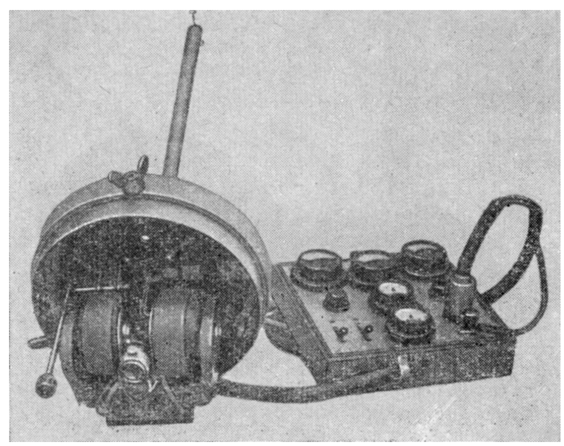

Figure 1. Transmitting head of Radio Direction Finder, 1935

After reorganisation they have proceeded in Scientific Research Institute number 9 (SRI-9). LEPhI was taken as a basis for a new SRI-9. Later SERI WPRA (Third Scientific School), SRI-20 (Fifth Scientific school) were joined to SRI-9 works.

The Third Radar Scientific school arose after ADA`s refusing to cooperate with LEPhI (after successful «Rapid» test equipment). It happened in autumn 1934. Probably, customer desire to have the work carried out by military experts was the reason of the change. At first it was ADA design department (DD ADA), then it was ADA Test Laboratory (TL ADA). It

was an association with CERI WPRA after a number of organizational transformations.

The Fourth Radar Scientific school based on the LPhTI and the Fifth radar Scientific school based on the UPTI in Kharkov emerged in late 1934 - early 1935 after receiving assignments from DD ADA (Third Scientific school).

The Sixth Radar Scientific school was established in Moscow (with a branch in Leningrad). It was the SRI-20. This institute was founded in September 1937 with a view to finalizing the pulsed Warning Radar (later RUS-2).

B. Magnetrons in the first Soviet radar projects

Financing of the magnetron development in the 1930s took place within the limits of radar projects. But the beginning of the magnetron development in the Soviet Union belongs to the earlier period.

In 1924, at the suggestion and under the guidance of Professor D. A. Roganskiy his pupil A. A. Slutskin and D. S. Shteinberg began research. They led to the development of the magnetron method of receiving electromagnetic waves with the shortest wavelength - about 7 cm. In 1925 A. A. Slutskin and D. S. Shteinberg published these studies and their results [1].

Further research in this area were conducted in the UPhTI department of the electromagnetic waves. A. A. Slutskin [1,3,11] became the scientific supervisor of this department in 1930. UFTI employees S. Ja. Braude [4,13, 24], E. A. Kapilovich [14], P. P. Lelyakov [9], A. P. Maidanov [10], A. A. Chernets [30], A. Y. Usikov [9] published their findings on cavity magnetron in technical journals in the 1930s. On the basis of theoretical work UFTI created the series of the magnetrons in the range from 20 to 80 cm with continuous power generation from 10 to 100 W. From September 1934 UFTI started to deliver magnetrons of different power and at different wavelengths to DD ADA.

Results of the UFTI magnetron studies were partly used in CRL (J. K. Korovin`s group) to build radio aircraft detection installations in early 1934 (2-segment split-anode magnetron, 20 cm wavelength, a few watts radiated power). Magnetrons were produced in A, A. Shaposhnikov`s laboratory, owned by the Leningrad Electrotechnical University (LETI). Magnetrons for the first experiment, which also carried by Y. K. Korovin`s group (2 segment split-anode magnetron, the 50-60 cm wavelength, 0.2 W radiated power) were made in the same laboratory.

Y. K. Korovin used the 4-segment split-anode magnetron (8 cm wave length, 8 W radiated power) in subsequent radar projects (1935-1937 years) carried out already in Gorky [2, 7, 12, 17, 23, 25, 27].

Information about the magnetron developments in LEFI is contained in B. K. Shembel`s memoirs [33]. He writes that the magnetrons produced in 1934 did not provided reliable working of the radiated generator. The wavelength was not sufficiently small, or with necessary radiated power . Similar results were obtained when Y. K. Korovin used his own magnetrons (developed by him). They differed by the lack of an internal circuit which fixed the wavelength, from the LEFI (by V. V. Tsimbalin) magnetrons developed in 1934. The magnetron anode had a very small diameter of 2 mm. This allowed the developers to reduce the capacitance between its two segments so, that it became possible to make direct exits to the cylinder and to set up a tuned external circuit.

These magnetrons were made in Prof. A. A. Shaposhnikov`s laboratory (LETI). They were better than the LEFI magnetrons, but also demonstrated an unstable behaviour, very “noisy”, and a tendency to "flare" of the cathode. As a result the valve is often destroyed.

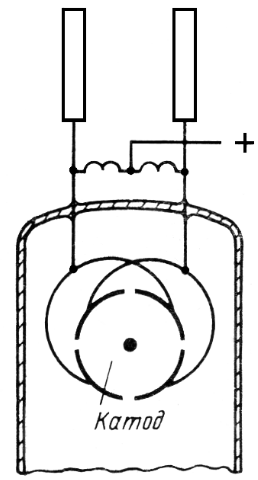

Figure 2. 4-segment magnetron.

The new 4-segment magnetrons (Fig.2) were much better than 2-segmented. They easily gave into load 8-15 W output at 21-29 cm wavelength. These magnetrons have the anode diameter of 5 mm and anode length of 10 mm with the same diameter glass cylinder. The main technical advantages were the ability to work at lower anode voltages and smaller magnetic fields (power consumed by the electromagnet decreased 4-fold). The magnetrons worked steadily and "outbreaks" of the cathode were no longer observed.

It should be noted that these magnetrons were produced in the laboratory conditions. Vacuum shops that existed in LEFI were over-booked and could not ensure high quality. The experience gained during the manufacture of two-segment magnetrons showed that the performance of valves is to a very large extent dependent upon the quality of installation and technology. Therefore, LEFI took steps on improvement of manufacture quality of new 4-segment magnetrons. As for its external oscillatory circuits, the design of the 4-segment magnetron was a transition towards a cavity magnetron. Unipolar anode segments are connected by bridges in this design, as well as in the future multi-resonator design. But there was a difference. The 4-segment magnetrons had a common oscillatory circuit, rather than 4 individual ones, as N.F. Alekseev and D.E. Malyarov did in the SRI-9 in 1936-1937, and as it is now in modern magnetrons.

Development of the magnetron technology required ways to improve the technical parameters of the magnetron. There are many factors such as the influence of the transit time of

electrons between the electrodes, the influence of internal valve capacitances and inductance of bushings, dielectric losses. radiation losses take place when valves work in any frequency range, but they become dominant in the microwave range. The construction of the magnetron reached technical perfection during a short time and the magnetron become the main type of the generator in power transmission devices.

SRI-9`s magnetron researches, as well as UPhTI`s magnetron researches were a major step forward in magnetron generator development. But it follows from the analysis of the data presented in Table 1, radars, taken into service by 1941 used other microwave devices (not magnetrons).

Pulse radar of the meter band (future RUS-2) with pulse generator valves (domestic production, first it was IG-7, then it was IG-8) was more promising because of the customer requirements and the state of the radio engineering and electronics industry. The idea of using cavity magnetrons was reborn only after WWII.

Basing on the analysis of the mentioned material it is possible to formulate some conclusions. The same type of works were distributed among different customers and artists for a long time. Geographical dispersion, weak communication and secrecy did not give an opportunity to develop universal scientific and technical policy, as well as to concentrate on implementing a single technical solution, to evaluate the significance of "incidental" results. The story of designing the cavity magnetron by N. F. Alekseev and D. E. Malyarov is a bright example of such "incidental" results. Their idea served as a prototype of modern cavity magnetrons in the Soviet Union and other countries.

C. History of invention so-called "Alekseev's and Malyarov's cavity magnetron"

Research and development in multi-resonator centimeter magnetrons was made by Alekseev and Malyarov, employees of SRI-9 NF on instructions and handwritten drafts of Bonch-Bruevich, SRI-9 supervisor, and under his leadership. This is confirmed by information provided by Alekseev in his handwritten autobiography.

Long ago in 1929, Bonch-Bruevich patented the idea of oscillating systems consisting of many units, to increase the capacity of tube generators. Here he applied this idea to create multi-resonator magnetrons. In August 1936 Alekseev and Malyarov first achieved encouraging results when testing a glass magnetron with a tungsten cathode and anode block with four resonators made from a sheet of tantalum. At the wavelength of 9 cm about 10 W of oscillatory power in continuous mode was obtained. In September 1936 Alekseev and Malyarov began developing multi-resonator magnetrons with a copper anode block, cooled under running water. In March-April 1937, these magnetrons gave at wavelength of 9 cm about 300 W of oscillatory power in a continuous mode with an efficiency of 20%.

Figure 3. Professor M. A. Bonch-Bruevich, . Science director of the SRI- 9. The main participant of the cavity magnetron development.

On the base of the experience with demountable magnetrons in the end of 1937 a few copies of "sealed" (e.g.without the pumps) magnetrons were made, these were magnetrons with a tungsten cathode, as well as with anode blocks in which there were four resonator gaps - holes. When working in a continuous mode, these magnetrons gave about 120 W of power with oscillational efficiency of up to 22,5%.

The same engineers developed similar four-cavity magnetrons at 1, 2·5, 5 and 7·5 cm wavelengths. Thus, in 1937-1938 Alekseev and Malyarov under Bonch-Bruevich's leadership created a series of multi-resonator magnetrons for the whole centimetric range.

All subsequent development of magnetrons in SRI-9 was carried out in the direction of improving multi-resonator systems of these structures.

In the article "Getting powerful oscillations of magnetrons in centimetre wavelength range", published in 1940, Alekseev and Malyarov summed up their development [22]. In 1944, this article was published in the United States in English, and in 1945 an American magazine published an overview paper on development of electronics, in which they evaluated the magnetron made by Alekseev and Malyarov. The author of this article wrote: "... In 1940 a new type of magnetron was described in Russian technical press by Alexeeev and Malyarov", and in 1944 a translation of their article was published in an American technical magazine.

The most important innovation is that instead of the usual outer contours hollow cavities were used, each cavity through its slot connected to the interaction space located in the centre. The authors report that at 9 cm wavelength they received oscillatory power of 300 W from such a tube. To estimate the significance of this type of magnetron, it is useful to recall that when Kilger from East Pittsburgh reported that he had received at about the same frequency of oscillation a magnetron power of one watt, the power did not seem to be "terribly big".

Alekseev and Malyarov did not stop here and in 1938 under the leadership of Bonch-Bruevich set up an experimental

installation of radio detection at 5 cm wavelength for making research at NII-9.

Later lives of the inventors went in different directions (see the postscript to the report). Bonch-Bruevich died in March 1940, a month before the publication of the article, which became world famous. Malyarov died in early 1942 during the siege of Leningrad. Alekseev taught radio technics until the end of his fundamental life (he died in 1984).

Figure 4. Leading engineers of the SRI-9. D. E. Malyarov is the first at the left in the first row. N. F Alekseev is the first on the right in the second row.

IV. WAR PERIOD (1941 – 1945)

By the beginning of war there were two types of long-range detection systems (“aircraft radiodetectors”, RUS-1 with a continuous radiation and pulsed RUS-2) in the air defense army. There were not many of them: 31 RUS-1 (only 28 in the army) and 2 RUS-2. As for anti-aircraft artillery NII-9 manufactured finder “Luna”, which was a good achievement, however they did not manage to organize mass production of this finder till the end of the war. Development of Ukrainian Zenit had been tested before the war, but was recommended to use it only as a supplement to the RUS-2. As it was shown in the review of the scientific base of radar projects, their main part was more of scientific and experimental and development work character. Pre-war industry remained weak, and they failed to establish commercial production of radar stations.

However at the beginning of the war the industry of the Soviet Union was even in a worse condition: many things were left under the bombs, many things were damaged during the evacuation, many industries had to be adapted to the needs of the army. In 1941, centres for development of radar projects, such as Leningrad, Moscow and Kharkov were at risk. In these conditions, extreme measures were needed to survive.

A resolution of the State Defense Committee “On the industrial base for production of radio detection and direction finding equipment of aircraft” from February 10, 1942 was the first step. According to this resolution in Moscow a new company (Institute-plant) able to conduct scientific development and produce radar equipment was organized. Former managers and staff of the Leningrad plants, SRI-9 and other businesses, were summoned to Moscow from evacuation, from the army, removed from the siege of Leningrad. Equipment from Leningrad for conducting a full production cycle of vacuum devices was delivered across Lake Ladoga. In a short time installations for producing vacuum devices of complete technological cycle of the cathode to the glass-blowing chemistry and brewing operations of pumping valves were mounted. As a result, over 25 types of generator, modulator, receiving-amplifying and other valves were developed and produced. In eight months, two prototypes of GL-MK-IIot - domestic analogues of British artillery station pickup were made. GL-MK-IIot worked on a wavelength of 4 m and gave an opportunity to detect aircraft at ranges from 20 to 40 km (at altitudes from 1000 to 4000 m) and to determine its coordinates. By the SDC decree dated December 20, 1942, GL-MK-IIot was put into service and put into batch production.

The Moscow company had no production space and capacity in order to fully meet the needs of the army in the stations of GL-MK-IIot. As a result of troop flak still experienced a shortage of radar stations pickup. To some extent the supply of radar equipment under Lend-Lease was a rescue. Only through the port of Murmansk in 1942 61 GL-MkII, and in 1943, 55 GL-MkII, 4 GL-MkIII and 39 miscellaneous pieces of technical equipment were received. There were great difficulties in dealing them due to the lack of military experts - radio operators.

The war made significant amendments to the plans of research and development work on radar. Evacuation of research institutes and industry to the east significantly obstructed the course of pre-existing research and development. However the work continued.

A resolution of the State Defense Committee “On establishment of State Defense Committee Council on radars” from 4th July 1943 was a very important step in the development of microwave technology (including magnetrons). Along with other decisions this decree marked the beginning of large-scale work on developing electronics industry in the Soviet Union. Accelerated deployment of radars production required expansion of the industrial base and involved a significant range of scientific, engineering and production personnel in the scope of their development. Here is the relative increase in production. RUS-2 and RUS -2s detection plants after the Council on radar appeared.

V. POST-WAR MAGNETRONS

After the war, in the Soviet Union magnetron issues were developing as one of the areas of electronics. Leaders at the highest level began to realize how important the results of electronics development for the country's defense were, as well as for the development of radar. In electronic and radio industries the highest-quality resources available at that time were used: equipment, labour, and supervisory personnel. The gap between technical and qualification level of military and civilian industry in the Soviet Union was significantly higher than in capitalist countries. But this was useless for making a revolutionary breakthrough. In the country devastated after the war there were not enough material, technical and human resources to accelerate the development of electronic and radio industries. Therefore, development of electronics (including

magnetrons) in post-war period was systematic and comprehensive. This helped to set a scientific and technical basis step by step for their own original developments, as well as gave an opportunity to get away from the practice of copying foreign models, which prevailed during the wartime.

Creating a radically new technology and the rapid use of available scientific achievements of other countries would have been impossible without skilled scientific and technical personnel. Immediately after the war a number of technical universities introduced new majors connected with the technique of microwave frequencies and increased the number of students accepted to study these branches. Training courses and textbooks were being developed. In the library of the A. S. Popov Central Museum of Communications many postwar books and publications on magnetron issues are stored. Promptness with which Russian translations of foreign publications appeared is especially notable. For example, one of the first major publications on magnetron issues, which appeared in 1946 in the US (the authors - D. Fisk, K. Hagstrum, P. Guthman, magazine – “The Bell System Technical Journal”) was published in Russian as a book in 1948. Russian translation was supplemented with the material on cathode magnetrons, published in other foreign journals (information on domestic developments). It is also necessary to recall the higher wages of highly qualified scientific workers immediately after the war and about the atmosphere of respect for the work of scientists and creators of new technologies.

Production was being organized step by step. Existing plants were redesigned, new ones were built. The largest enterprises of Electronics and Electrovacuum industry, which produce magnetrons nowadays are as follows: Fryazino multidisciplinary Institute (now the "Istok"), the Moscow Electric Lamp Plant (now the "Pluto"), Leningrad factory "Svetlana", Saratov factory "Tantalus". The list of enterprises mentioned as ones producing magnetrons is not full. Magnetron issues developed throughout the country on the basis of the factories and institutions, evacuated during the war. As the demand in magnetrons grew, productions which could be converted with the greatest efficiency were found. New factories were built.

Questions concerning magnetrons were being solved at the highest governmental and scientific level. Here is just one example from the history of Fryazino "Istok" [38].

In 1960, in the Fedorovs's office (he was director of "Istok" from 1953 to 1961 a historic meeting was held. The issue on the agenda was, which direction in the development of microwave devices should be chosen - magnetron or klystron. A. P. Fedoseev and S. A. Zusmanovsky were reporting. The people present: Adviser on radio-electronic weapons to the Head of the Soviet State Khrushchev, Minister of Radio Kalmykov, academician Kapitsa, academician Weinstein, Ph.Ds, Directors of the SRI and many other prominent specialists in radio electronics. Fedoseev briefly and clearly stated: "If there is no MI-138 (magnetron" Albatross "), we will not win the field." Khrushchev's counselor said that he would report everything to the government and would inform about the decision. The solution was made - to develop magnetron direction. For reference, a MI-138 magnetron was used in the modernized system, C-25, which in those years was the basis for air defense in Moscow, as well as in many other major industrial centers in the Soviet Union.

As a result, a plant for producing magnetrons was built in Izhevsk. Technological and production discipline in the new production significantly reduced the proportion of flaws that took place when other plants were producing magnetrons. Having started to develop production from the very beginning, factory experts in a short time managed not only to increase yield, but also to make a number of significant improvements in devices that increased reliability and durability of magnetrons.

One can find information on the technical aspects and improvement of the parameters of the magnetron technology in the postwar period (and present) in numerous publications [32, 34-36].

VI. CONCLUSION

From the panoramic view, presented in the report, comprehension of the causes of the rapid development and inhibition, successes and failures in the evolution of domestic cavity magnetrons appears. This story is inextricably connected with the history of our country and the difficulties that accompany the establishment of national electronic industry, such as political situation, administrative-command system of governance and economy.

The paper reveals how Soviet engineers were looking for pioneering technical solutions in magnetron technology. It also explores the role of different groups and people. Particular attention is drawn to the historical injustice against Mikhail A. Bonch-Bruevich, whose name (along with Nicholay F. Alekseev and Dmitry E Malyarov) is not usually associated with the creation of a famous powerful cavity magnetron.

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VII. POSTSCRIPT – BIOGRAPHICAL DATA

1. M.A.Bonch-Bruevich (1888-1940)

An outstanding Soviet scientist, radio engineer, inventor Michail Aleksandrovich Bonch-Bruevich was born on 22nd February 1888 in the Russian Empire (city of Orel). He was well educated. In 1909 Bonch-Bruevich finished at the Nikolaev military engineering school in St. Petersburg. Having served three years in engineering armies (in Irkutsk) he entered Officer Electrotechnical School in St. Petersburg. The school had a status of a higher educational institution, and the best experts in the country taught there.

After leaving school which coincided with the beginning of WWI, the lieutenant Bonch-Bruevich was appointed to a new radio reception station in Tver (between the cities of St. Petersburg and Moscow). Radio reception was supported by means of valve amplifiers constructed using foreign valves. Electrovacuum valves were not manufactured in Russia at that time. Bonch-Bruevich became the person who has organised laboratory manufacture of the first Russian electronic lamps (so-called «cathodic relays») by the beginning of 1915. Even before the revolution in 1917 in Tver in so-called «non-staff laboratory» about 3000 pieces of the hollow valves which subsequently have received the name "grandmother" were manufactured. It is where collected about 100 receivers, so-called «cathodic breakers» according to a difficult scheme offered by Bonch-Bruevich. The new revolutionary authorities understood the advantages as well as scientific and technical potential of this small military laboratory in Tver and created on its base (with moving of employees and property) the Nizhny Novgorod radio laboratory.

From 1918 a new period of Bonch-Bruevich activity begun (in the Nizhny Novgorod radio laboratory). Research enterprise with industrial workshops (modern for those times) was created with Bonch-Bruevich's participation for short term in the conditions of the hunger and ruin. Without stopping on reached (an electronic lamp as means of low frequency strengthening) Bonch-Bruevich again gone forward and developed designs of powerful generating valves, reached successes in radio telephony. In 1922 on Lenin`s instructions Bonch-Bruevich constructed the first-ever powerful (12 kW) Komintern`s broadcasting station in Moscow. In 1927 the broadcasting station (40 kW) with Bonch-Bruevich`s radio valves started in Moscow .

In 1924-1930 Bonch-Bruevich supervised over studying of the short waves distribution, working out of the first short-wave directed action aerials and the building of the short wave telecommunication lines.

Having moved to Leningrad in 1928, Bonch-Bruevich worked also over questions of the radio-wave distribution in the upper atmosphere. For the first time in the USSR he raised the question about research of the top ionosphere layers by the method of pulse parcels ("radio echo") which was taken further as a radar principle.

In 1921 Bonch-Bruevich was selected as the professor of the Nizhny Novgorod University. Since 1922 he was the professor of the Moscow Higher Technical School, and since 1932 he was the professor of the Leningrad Institute of Communication Engineers (nowadays it carries his name). Since 1931 he was corresponding member of the USSR Academy of the Sciences. Bonch-Bruevich's numerous scientific merits formed the basis to his election in the member-correspondents of the USSR Academy of the Sciences. The Bonch-Bruevich's proceedings, radio engineering textbooks, monography concern, mainly, the work period in Leningrad. Bonch-Bruevich was the author of many patented inventions.

Since 1935 up to the death (in March, 1940) Bonch-Bruevich was the scientific supervisor of the SRI-9. He headed the researches of some difficult scientific problems, including working out of the radar stations.

In 1935 he submitted the idea of the cavity magnetron to engineers (Alekseev and Malyarov). This cavity magnetron became the basic source of powerful UHF fluctuations. Bonch-Bruevich never did secrets of the inventions and always specified in the patent those who had though the slightest relation to work He was alien to small envy, rejoiced to successes of others feeling the big creative possibilities in itself. He was possible to surround itself by young engineers who realised his undertakings. The case with the cavity magnetron was only one of this series.

M.A.Bonch-Bruevich has died in Leningrad on 7th March 1940 at the age of 52 years. A difficult life, old poisoning with mercury steams, political problems (Bonch-Bruevich was rehabilitated shortly before death, and before that he was subjected to repression together with a number of other SRI-9 employees) - it all led to his death.

The Malyarov-Alekseev's known article arrived in magazine edition in April, 1940 (already after Bonch-Bruevich's death).

2. D.E.Malyarov (1903-1942)

D.E.Malyarov was a little older than 30 when he was developing magnetrons. Speaking about the most famous work (cavity magnetron) they often write that its authors (Malyarov and Alekseev) are: version 1 - scientists, version 2 - engineers. Malyarov was neither a scientist, nor an engineer, only a fine experimentalist. But what an experimentalist! By some quirk of fate the young man experienced the practical school of electrolamp manufacturing in the twenties in a famous Nizhny Novgorod radio laboratory and became connected with M.A.Bonch-Bruevich. How did it happen?

Dmitry Evgenevich Malyarov was born on 20th June, (or 3rd July) 1903 in a family of a priest. He could not finish secondary school as his family had to move from place to place. These were years of war - at first WWI, then revolution in 1917 and civil war. In 1917 Malyarov's family moved to the Kharkov province and lived there till 1920 — to the father's death. Malyarov became ill with a typhus in January, 1921. The country was in ruins, there was a civil war and hunger. Young man who had not absolutely recovered after a typhus went to Nizhny Novgorod to his aunt Julia Illarionovna Lebedinskaya, the spouse of professor V.K.Lebedinsky. The professor worked as the leading expert in NRL. After recovery the young man started to work in the same place in M.A.Bonch-Bruevich's department of the NRL. Then, in 1921, Malyarov entered the chemical faculty of the Nizhny Novgorod State University which he could not end owing to intense experimental work in NRL. After this Malyarov tried to finish higher education at electrotechnical faculty, but he did not graduate.

Absence of the formal educational document did not prevent him from performing difficult experimental works. In Bonch-Bruevich's department Malyarov took the most active part in working out of the super-power radio valves with the anode cooled by water, of the special VHF electronic valves and others. Malyarov got nickname "maestro" for the outstanding experimental art and fine technological skills.

In the end of 1928 Malyarov moved to Leningrad together with all collective of the NRL. He continued to work under the Bonch-Bruevich`s direction in the CRL. Malyarov came into contact with factory "Svetlana" laboratory where some NRL`s colleagues worked. They solved the problem with manufacture of copper valves with external cooling of the anodes. Experiments (on Bonch-Bruevich`s instructions) with tetrodes were the first of Malyarov`s works in Leningrad. Then Malyarov worked with gas-discharge devices and high-frequency light modulation for TV.

In 1935 Bonch-Bruevich headed research work at the new institute SRI-9. He immediately involved Malyarov in SRI-9. Malyarov with Alekseev carried out the researches devoted to generating of UHF radio-waves. They developed the cavity magnetron (received world popularity) and also a number of other works.

It is necessary to mention some qualities of Malyarov`s character. His spiritual interests left far beyond current laboratory works. Malyarov read much, showing the greatest interest to philosophical compositions. On memoirs of the colleagues he «making to itself too high demands, usually refused flatly to publish the results received by him, being content with that they met with approval of his management and companions». And here are still responses about Malyarov: « … almost painful modesty corresponded to his closed character though it was impossible to name him unsociable — he always was one of the most brisk among the contemporaries … ». He did not have the family and near relations. He was the lonely person in essence. Professor Lebedinsky who has sheltered him in NRL in 1921 was the closest person for Malyarov, but Lebedinsky died in 1937. After Bonch-Bruevich's death Malyarov continued to work in the same SRI-9 (even after the beginning of Great Patriotic War in 1941 and during Leningrad blockade). On 16th February 1942 he died in Leningrad of an exhaustion, absolutely lonely. He was only 38 years old. Malyarov did not

live the few additional days until the remaining SRI-9`s employees were evacuated to Moscow through Ladoga`s life road in March 1942.

3. N.F.Alekseev (1910-1984)

There was more safety in the destiny of the other participant (Alekseev) of the group which created the well-known design of the cavity magnetron. He did not become a well-known scientist or administrative leader. Most likely it relieved him of the prosecutions and reprisals in those dashing years. Remaining all long life true to the chosen trade, Alekseev devoted himself to university teaching activity.

Nikolay Fedorovich Alekseev was born on 27th February 1910 in Leningrad (in the family of the worker as he wrote in the autobiography). From 1917 to 1927 Alekseev trained in the school in Leningrad. After leaving school he arrived on physicomechanical faculty of the Leningrad Polytechnical Institute.

In 1931, after reception of the diploma, Alekseev started to work as the scientific employee at the LEFI in the laboratory of well-known academician N.D.Papaleksi. At first he participated in parametrical resonance researches. Then Alekseev performed independent work which was marked by the first publication in Magazine of Technical Physics «About Influence of Electronic Stream on Triode Grid-Anode Capacity ».

Alekseev taught in parallel with the main work. From April 1931 until June, 1934 Alekseev taught physics at the Leningrad First Medical Institute; from September 1934 until June, 1936 he gave the lectures and the practical training on the radio engineering at the Leningrad Institute of the Railway Engineers; since September 1935 until November 1936 gave lectures on the course “Radio transmitters” in the Budyonny`s Leningrad Military Electrotechnical Academy.

In 1935 Alekseev moved to SRI-9. He worked as the senior engineer in the Bonch-Bruevich`s laboratory. Alekseev with Malyarov under Bonch-Bruevich`s direction developed the powerful generating sources in the centimetric wave band during the period from 1935 to 1939. In June of 1940 Alekseev was appointed as the deputy chief, and in 1941 as the chief of the laboratory. It is necessary to notice that the further Alekseev`s military destiny was defined by one more work executed together with Malyarov. By the end of 1941 (already in the blockaded Leningrad) they developed Device "Our-Another's" (DOA). It was necessary to use storage batteries from all laboratories for this purpose. The Institute power supplies were disconnected at once as the blockade of Leningrad begun (in September, 1941). In 1942 this model was transported to Moscow together with evacuation of the remained employees and some equipments. Using the principle of that model, Alekseev created device DOA-3 with E.H Genishta and V.I.Appel. The DOA-3 passed all tests and was accepted on the arms. Alekseev was rewarded by the «Red star».

After WWII Alekseev worked in Germany in the Radar Commission (from August 1946 until April 1947).

After returning to Soviet Union he was invited as the teacher in the Moscow Aviation Institute (MAI). From 1950 to 1954 Alekseev worked as the radio faculty dean. Alekseev defended his Ph.D dissertation in 1955. The dissertation theme was «Research of the process of the fluctuation establishments in the decimeter wave band oscillator». Alekseev worked as the Doctor of the radio engineering department in MAI after the defence of the dissertation and till his last days (almost 30 years). This work has been interrupted only once (1962-1964) when he was sent to India for teaching work. Alekseev gave lectures « UHF electronic devices » and «Electronic and semi-conductor devices» as the professor of the Madrass Institute of Technology (India). Alekseev died on 12th March 1984.

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TABLE I. SCIENTIFIC BASE OF THE FIRST RADAR PROJECTS

Scientific base of the first radar projects (October 1933 - June 1941) and their results							
Customer	MAA		ADA	ADA till 1937, CA – since 1937			
Scientific School	№1	№2		№3	№4	№5	№6
Civil / Military	Civil	Civil		Military	Civil	Civil	Civil
Contractor	CRL/ CMIRL	LEPhI/ SRI-9	LEPhI	DD- ADA / TL – ADA / CERI RKKA	LPhTI	UPhTI	SRI-20
Some famous names of scientists and engineers	Korovin J.K. Tropilo V. A. Kalinin V.I. Tsimbalin V.V. Grehova M. T.	Bonch-Bruevich M. A. Vvedenskiy B.A. Malyarov Д.Е. Alekseev N.F.	Chernyshev A.A. Rozhanskiy D.A. Shembel B.K.	Oshchepkov P. K Stogov D.S.	Ioffe A.F. Rozhanskiy D.A. Kobzarev J.B. Chernetsov N.J. Pogorelko P. A.	Rozhanskiy D.A. Slutskin A.A. Shteynberg D.S. Braude S.J.	Slepushkin A.B.
City	Leningrad-Gorkiy	Leningrad	Leningrad	Leningrad-Moscow	Leningrad	Kharkov	Moscow - Leningrad
Years	1933-1937	1934-1941	1934-1935	1934-1941	1934-1941	1934-1941	1937-1941
Name	The first installation of radio- based aircraft detection. Enot.	Stal, Burya, Groza, Strelets, B-2, B-3, Mimas, Luna, etc.	Rapid	Vega, Konus, Reven, RUS -1, RUS -2 , etc.	RUS -2	Separate cavity magnetrons , Zenit, Rubin	RUS -2
Radiation	continuous	continuous	continuous	continuous / pulse	pulse	continuous / pulse	pulse
Microwave device	cavity magnetron	cavity magnetron	cavity magnetron	G-165/PG-8	PG-8	cavity magnetron	PG-8
Result							
Experiment, pre-production model	+	+	+	+	+	+	+
Production of the radar-series started (31 pieces)	–	-	-	RUS-1	–	-	-
Production of the radar-series was recommended (2 pieces)		-	-	RUS -2	RUS -2	-	RUS -2

TABLE II. LIST OF SYMBOLS

EN/ RU	Explanation
ADA/ УПВО	Anti-aircraft Defence Administration (equal Upravlenie ProtivoVozdushnoy Oboroni UPVO)
CERI WPRA / НИИИС РККА	Communication Experimental Research Institute of Workers'–Peasants' Red Army
CMIRL / ЦВИРЛ	Central Military-Industrial Radio Laboratory (till 1929-NRL, since 1939 - Gorki State factory number 326). City of Gorkiy is equal city of Nizhny Novgorod.
CRL / ЦРЛ	Central Radio Laboratory
DD/КБ	Design Department
GL-MKIIot / СОН -2от	Russian analogue of the GL-MK II
LEPhI / ЛЭФИ	Leningrad ElectroPhysical Institute
LPhTI/ ЛФТИ	Leningrad Physical-Technical Institute
LETI / ЛЭТИ	Leningrad Electrotechnical University
MAA / ГАУ	Main Artillery Administration
NCB / НКО	National Commissariat of Defense (equal Narodny Komissariat Oborony NKO)
NRL /НРЛ	Nizhny Novgorod Radio Laboratory
PG / ИГ	Pulse generation
RDF / РП	Radio Direction Finder
RUS / РУС	RadioUlavlivatel Samoletov (Literal translation of Russian abbreviation is Radio Catcher of Aircrafts. Sense translation is Warning Radar)
SDC / ГКО	State Defense Committee
SRI-9/ НИИ-9	Scientific Research Institute - number 9
SRI-20/ НИИ-20	Scientific Research Institute - number 20
TL /ТЛ	Test Laboratory
UPhTI / УФТИ	Ukrainian Physical-Technical Institute
UHF / УКВ	Ultra High Frequency
WPRA / РККА	Workers'– Peasants' Red Army, (equal Raboche-Krest'yanskaya Krasnaya Armiya RKKA). Since 1943 – the Soviet Army